Nuclear physics

Unit - I

(*) i) Define Radioactivity?
ii) Find an Expression of radio activity disintegration with time.

(OR).

P.T. $N = N_0 e^{-\lambda t}$, N = number of radioactivity atom at time 't'.
λ = disintegration const.

iii) Find an Expression mean life time and half life time?

→ (i) → The heavier nucleus Emit's α, β Particle's and γ-ray for the stability of the nucleus this phenomenone is known as radioactivity.

for Example :- U^{235}_{92}, U^{238}_{92} radioactive isotope's of Urenium.

(ii) → Let, at time $t = 0$, there are N_0 number of radioactive nucleus present at the sample.

at time, $t' = t$, the no. of radioactive nucleus equal to N.

the rate of disintegration,

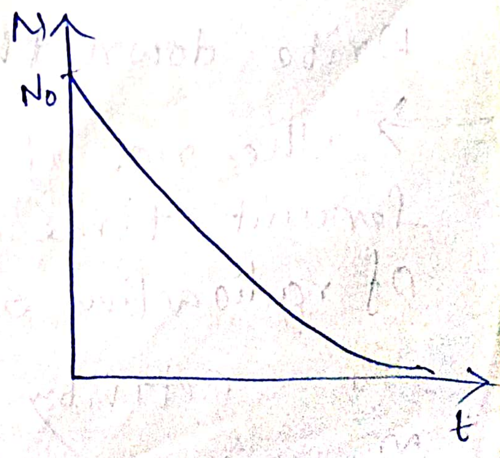
$$\frac{dN}{dt} \propto -N$$

$$\Rightarrow \frac{dN}{dt} = -\lambda N$$

$$\Rightarrow \int_{N_0}^{N} \frac{dN}{N} = -\int_0^t \lambda dt$$

$$\Rightarrow \ln\left(\frac{N}{N_0}\right) = -\lambda t$$

$$\Rightarrow \boxed{N = N_0 e^{-\lambda t}}$$



This is also known as disintegration equ^n.

(iii) → The time at which the no. of radioactive atom's become half of the initial no. of radioactive atom is known as half life.

at, $t = t_{1/2}$, $N = \frac{N_0}{2}$

$\therefore \frac{N_0}{2} = N_0 e^{-\lambda t_{1/2}}$

$\Rightarrow e^{\lambda t_{1/2}} = 2$

$\Rightarrow \boxed{t_{1/2} = \frac{0.693}{\lambda}}$

the time at which no. of Particle is become $\frac{1}{e}$ time's of it's initial no. of Particle, this time is known as mean-time.

at, time, $t = \tau$, $N = \frac{N_0}{e}$

$\therefore \frac{N_0}{e} = N_0 e^{-\lambda \tau}$

$\Rightarrow \boxed{\tau = \frac{1}{\lambda}}$.

$\therefore \boxed{t_{1/2} = 0.693\,\tau}$ $\{\tau > t_{1/2}\}$

⊛ Define activity of a radioactive sample! Write down the unit of activity?

→ The no. of radioactive disintegration per unit time is known as activity of radioactive sample.

$\text{activity} = \left|\frac{dN}{dt}\right| = \lambda N$

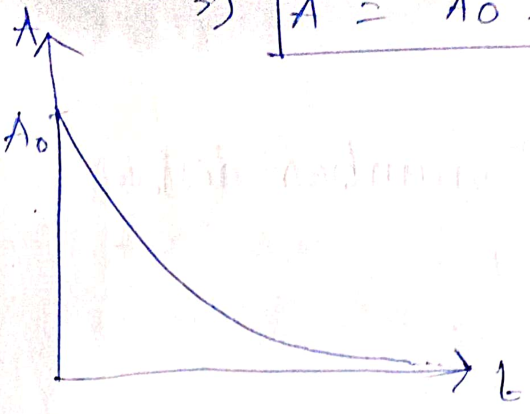
as, $N = N_0 e^{-\lambda t}$

$\Rightarrow \lambda N = \lambda N_0 e^{-\lambda t}$

$\Rightarrow \boxed{A = A_0 e^{-\lambda t}}$

A = activity at time 't'.

A_0 = activity at time ~~at~~ 't = 0'



unit → Bq (Bequerel)

1 Bq = 1 DPS [Disintegration per second]

(*) Half life of C^{14} is 12 years. ⟹ find number of C^{14} atom present after 10 year, if initially 10 gm of C^{14} is present.

→ N_0 = 10 gm.

$$t_{1/2} = \frac{0.693}{\lambda} \Rightarrow \lambda = \frac{0.693}{12} = 0.05775$$

$$\therefore N = 10\, e^{-0.05775}$$

$$\Rightarrow N = 10 \times 0.5612$$

$$\Rightarrow N = 5.612 \text{ gm}$$

14 gm ⟶ 6.022×10^{23}

$\therefore$ 1 " ⟶ $\frac{6.022 \times 10^{23}}{14}$

$\therefore$ 5.612 gm ⟶ $\frac{6.022 \times 10^{23} \times 5.612}{14}$

$= 2.413 \times 10^{23}$ atom's

(*) i) Discuss about different types of nucles.

ii) Find the relation between radius of atom and mass number. Hence find the density of ~~atom~~ nucleus.

→ (i) isotope :- Same no. of Proton / atomic no. and different mass no. $_6C^{12}$, $_6C^{14}$

isobar :- Same mass number and differed atomic number / Proton number.

$_7N^{14}$, $_6C^{14}$.

isotone :- Same nutron number diffrent Proton no.

$_7N^{14}$, $_8O^{15}$.

Mirror nucleus :- The nutron no. of 1st nucleus, is equal to Proton number of 2nd nucleus and Proton no of 1st nucleus equal to nutron no. of 2nd nucleus.

$_9F^{17}$, $_8O^{17}$

$P = 9$ $P = 8$

$N = 8$ $N = 9$

(ii) The volume of nucleus $\propto$ mass no

$$\frac{4}{3}\pi R^3 \propto A.$$

$$\Rightarrow R^3 \propto A$$

$$\Rightarrow \boxed{R = R_0 A^{1/3}}$$, $R_0 = 1.4 fm$ $A<30$

$= 1.2 fm$ $A>30$

This is the relation between radius of the nucleus and the mass number of the nucleus.

$$\text{density} (\rho) = \frac{\text{Mass}}{\text{volume}}$$

$$= \frac{A \times m_p}{\frac{4}{3}\pi R^3}$$

$$\Rightarrow \frac{A\, m_p}{\frac{4}{3}\pi R_0^3 A}$$

$= \frac{3 m_p}{4\pi R_0^3}$ $m_p = 1.67 \times 10^{-27}$ kg.

$R_0 = 1.4 \times 10^{-15}$ m.

$=$

$\simeq 1.4 \times 10^{17}$ kg/m^3

⊛ Define Mass defect of a nucleus and binding energy of nucleus. Find the relation between them?

→ The difference in mass of a nucleus and it's constituent nucleon's is called the mass defect of that nucleus.

$$\Delta M = Z m_p + (A - Z) m_n - M \text{ (mass of nucleus)}$$

The Energy equivalent of the mass defect of a nucleus is called its binding energy.

$$BE = \Delta M c^2$$

⊛ Draw the graph of binding Energy per nucleon Vs mass number graph. Hence Discuss Different information obtain from this graph?

→

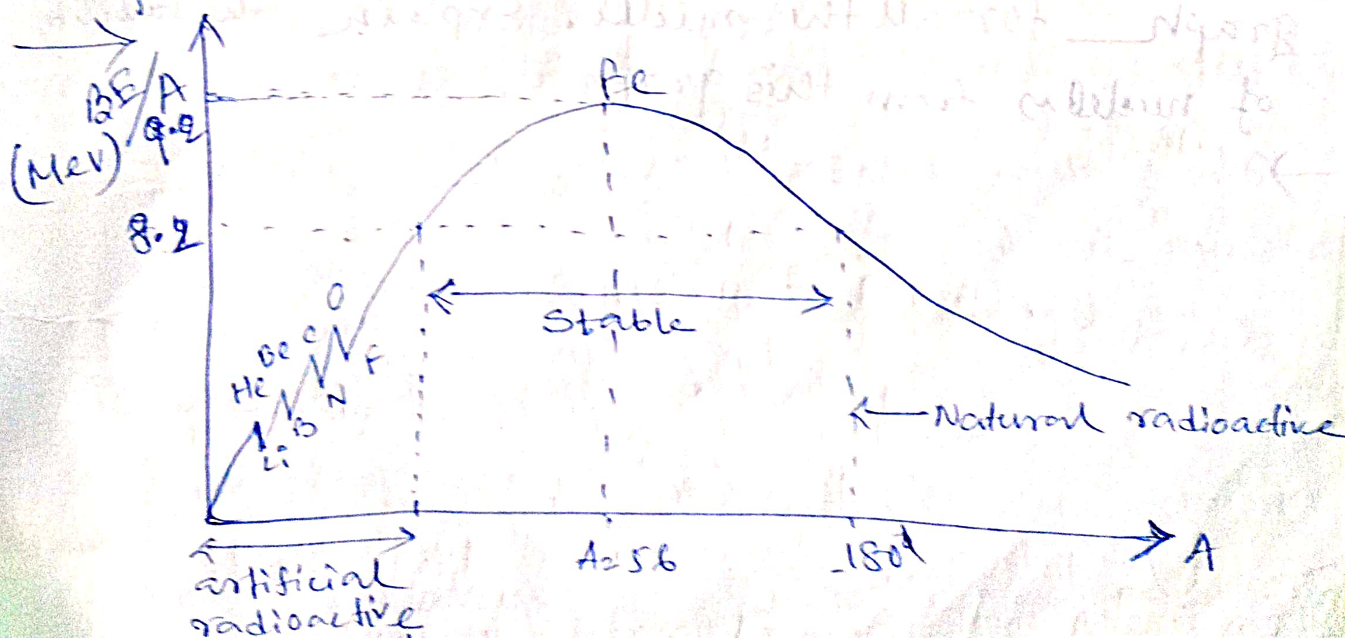


fig:- Binding energy per nucleone vs mass no. graph

Various feature's of BB/A vs A graph:-

(a)(i) BE/A increases with mass number and reache's a maximum value of 9.2 Mev/ per nucleon for mass no. 56 (Fe). after mass no. 56 BE per nucleon decreases with increasing mass number. after mass no. 180 BE/A almost saturated to a value 8 Mev/nucleon.

(ii) For the nuclei, having mass no. less than 20, there are some Pick's in the BE graph corrosponding to even-even number of Proton, nuetron such as $_{2}He^{4}$, $_{4}Be^{8}$, $_{6}C^{12}$, $_{8}O^{16}$ etc

(iii) nuclei having mass no. greater than 180 are naturally radioactive due to less bingding energy per nucleon.

the nuclei with mass no. less than 30, can be easily converted to artifical radioactive nuclei, as the BE/A is less.

(*) Draw the nutron no. vs proton number graph for all the nuclei. Explain the stability of nucleus from this graph.

→

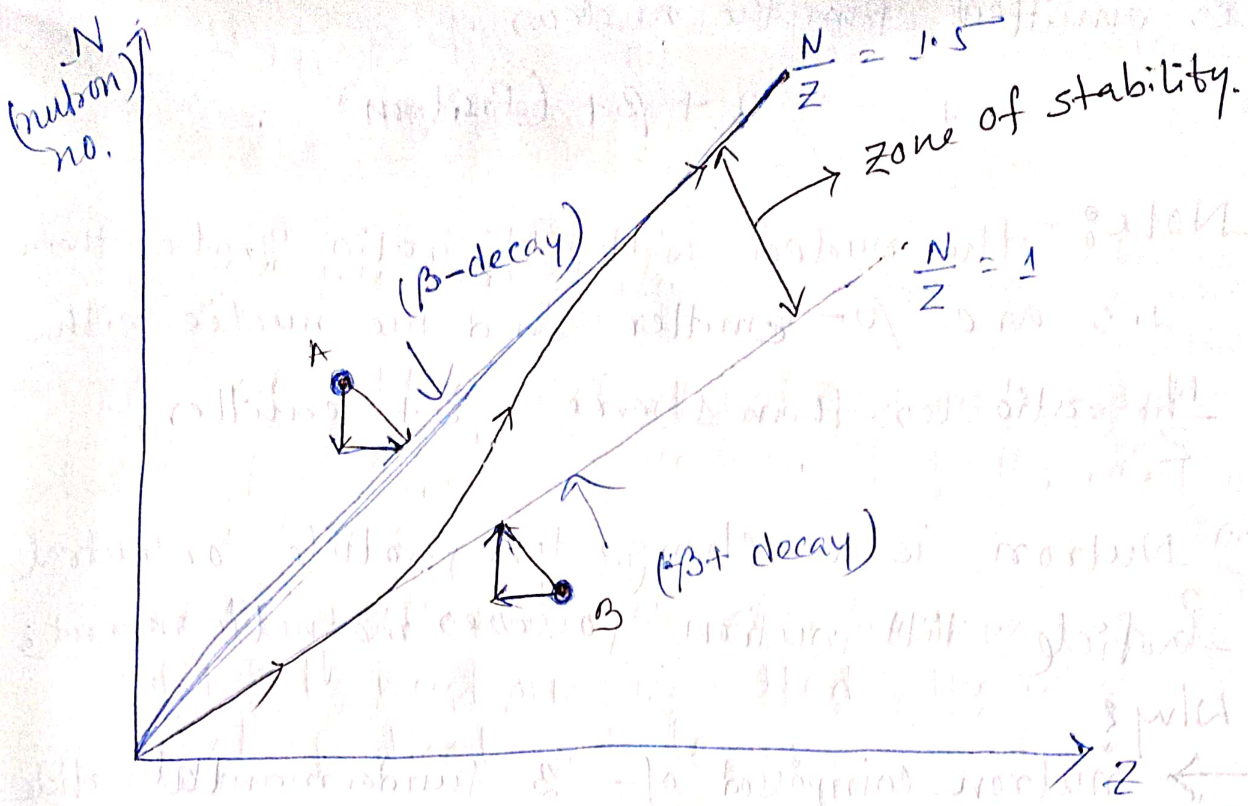


fig :- nutron no. vs Proton no. graph

for lighter stable ~~st~~ nucleus like C, N, O, the N/Z ratio is 1 and for havier stable nucleus like, Pb, Au, Pt the N/Z is 1.5.

the N/Z graph for all the stable nucleuses is inbetween $\frac{N}{Z} = 1$ and $\frac{N}{Z} = 1.5$ as shown in the figure this range $1 \leq \frac{N}{Z} \leq 1.5$ is known as zone of stability.

We considere a radioactive nuclie A with $\frac{N}{Z}$ ratio gratter than 1.5. For the stability of this nucleus nutron is converted to Proton ~~when~~ and β^-/e^- is emited from the nucleus.

$$n \longrightarrow P + e^- \ (\beta^- \text{ Particle})$$

Anothere radioactive nuclei with ~~mass no~~ $\frac{N}{Z}$ ratio Less than 1. For the stability of this nucleus Proton is converted to nutron and β^+ ~~e~~ (Positron)

is emitted from the nucleus.

$$p \longrightarrow n + \beta+ \text{ (Positron)}.$$

Note:- the nuclei with N/Z ratio grater than 1.5 are $\beta-$ Emitter and the nuclei with $\frac{N}{Z}$ ratio less than 1 are $\beta+$ emitter.

(*) Nutron is a charge less particle or nutral particle till nutron posseses magnetic moment, why?

→ nutron composed of 3-fundamantal particle 2-down quarks (charge:- $\frac{1}{3}e$) 1 up quarks (charge: $\frac{2}{3}e$).

As a whole nutron is charge less but due to quark's particle nutron has magnetic moment.

(*) Write down the unit of Magnetic moment of nucleous ? why nucleous posseses magnetic moment?

→ Nucllius is composed of proton's and nutron, both Proton and nuetron has spin about their own axis. Proton is charge particle and nutron is composed of fundamantal charge particle quark's and a magnetic moment is generated due to spin of proton and nutron. That's why nucleus posseses magnetic moment.

the unit of nuclear Magnetic

moment is nuclear maggneton (μ_N).

$$\mu_N = \frac{e\hbar}{2 m_n} = 5.05 \times 10^{-27} \, J/Tesla.$$

$$= 5.05 \times 10^{-27} \, Amp-m^2$$

m_n = mass of nutron

(*) why electric dipole moment of nucleus is always zero?

Nucleare Model's

(*) i) Write down the different feature's of nucleous that can be explain liquid drop model?

ii) write down the basic assumption's of liquid drop model's?

→ ii) Basic assumption's of liquid drop model

(i) in liquid drop model we consider a nucleous as a impossible matter or liquid.

(ii) the nuclear force is identical for every nucleon

(iii) nuclear force saturate.

(iv) In an equilibrium state, the nuclei of an atom remain sperically symetric under the action of strong attractive nuclear force.

(i) similarity between nucleous and liquid drop model:-

(i) the nuclear force is analogas to the surface tension force of a liquid.

(ii) the nucleon's behave in a meanere similar to the molecule's in a liquid.

(iii) the density of nucleous is almost independent of mass number and the density is const. this is similar to incompressible liquid drop.

(iv) the binding energy per nucleon is analoges to the latent heat of vapourisation.

(v) the disintegration of nuclei by the emission of particle's is analoges to the Vapourisation of the molecules from the Surface of the liquid.

(*) Write down the limitation's of liquid drop model.

→ (i) The liquid drop model fail's to explain the high stability of nuclei with magic numbers

(ii) This model does not explain the measured spin and magnetic moment of the nuclei.

(*) Write down bethe-weizsacker mass formula, mentioning each term?

ii) Using liquid drop model derive bethe weizsacker mass formula. or Semi-emperical mass formula. OR

→ Derive semi-emperical mass formula for Binding energy of nucleus. → Experimental.

→ According to semi-emperical mass formula for binding energy. for a nucleus of mass no. A and atomic no. Z is given by;

$$BE = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_{as} \frac{(A-2Z)^2}{A} + (0, \pm a_p A^{-3/4})$$

where,

a_v, a_s, a_c, a_{as}, a_p are constants related to, volume energy, surface energy, Coloumb energy, assymetric energy, pairing energy,

(ii) (i) Volume energy term:-

let, the interaction energy between two nucleon's due to strong nuclear force = u.

for each nucleon interaction energy $= u/2$

Due to high density of nucleons co-ordination no. = 12. (co-ordination no. = nearest nucleon no.)

So, interacting energy generated by nucleon

$= \frac{u}{2} \times 12$

For all the nucleon's interaction energy $= 6u$.

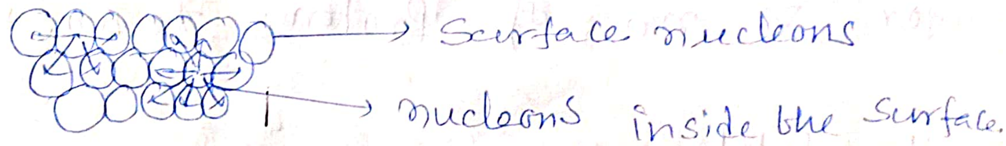
due to nuclear force $= 6uA$.

this energy is known as volume energy

term $= 6uA$

$\boxed{E_V = a_V A.}$, a_V = const.

(ii) Surface energy term:-



the nucleons present on the surface donot contribute in volume energy term because, the force on this nucleon's are not symetric and the resultant nuclear force on this nucleons towards the core of the nucleus.

This symetric force nuclear force try's to break the shape of the nucleus.

Surface area of a nucleus $= 4\pi R^2$, R = radius of the

$R = R_0 A^{1/3}$ — Mass no.

the no. of nucleon's on the Surface $\propto$ Surface area of the nucleus

Surface energy $\propto$ surface area.

$\propto -4\pi R^2$

$\propto -4\pi R_0^2 A^{2/3}$

$$\boxed{E_s = -a_s A^{2/3}}$$

(iii) Coloumb Energy term:-

Due to the repulsive force between Proton-Proton binding energy decreases.

the Coloumb energy or Potential energy generated due to repultion of two Protons $= \frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{r}$

r = Separation betwen two Proton.

for, Z no. of Proton's the no. of interactions $= \frac{Z(Z-1)}{2}$

the total Culoumb energy, $= -\frac{1}{4\pi\epsilon_0} \frac{e^2 Z(Z-1)}{r_{av.} \cdot 2}$,

$r_{av} \approx R = r_0 A^{1/3}$

$= -\frac{e^2}{8\pi\epsilon_0} \frac{Z(Z-1)}{r_0 A^{1/3}}$

$$\boxed{E_c = -a_c \frac{Z(Z-1)}{A^{1/3}}}$$

(iv) Asymetric Energy term:-

From the experimental data the stability of nucleus decreases with the increase in the difference between proton and nutron no. in a nucleus,

But, stability increases due to increasing mass no. [From volume energy term].

asyymetric energy term $E_{as} = -a_{as} \frac{(N-Z)^2}{A}$

$$\boxed{E_{as} = -a_{as} \frac{(A-2Z)^2}{A}}$$

(v) Pairing Energy term:-

the proton's and nutron's of a nucleus form's shell's like structure similar to electron's.

the nucleus with even even no. of proton nutron's are more stable as compare to nucleus with odd-odd no. of proton-nutron.

From experimental data,

$$E_p = a_p A^{-3/4}, \text{ for even-even}$$

$$= -a_p A^{-3/4}, \text{ for odd, odd.}$$

$$= 0, \text{ even-odd / odd-even}$$

a_p = const.

* Using semi-empirical mass formula find the atomic number of most stable isobar.

→ Isobar → same mass no. different atomic no.

from, semi-emperical mass formula,

$$BE = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_{as} \frac{(A-2Z)^2}{A} \pm a_p$$

$$\frac{\partial BE}{\partial Z} = -\frac{a_c}{A^{1/3}}(2Z-1) + 4a_{as}\frac{(A-2Z)}{A}$$

$$\Rightarrow 0 = -\frac{a_c(2Z-1)}{A^{1/3}} + 4a_{as}\frac{(A-2Z)}{A}$$

$$\Rightarrow 0 = -\frac{2a_c Z}{A^{1/3}} + \frac{a_c}{A^{1/3}} + 4a_{as} - \frac{4a_{as} 2Z}{A}$$

$$\Rightarrow Z\left(\frac{2a_c}{A^{1/3}} + \frac{8a_{as}}{A}\right) = \frac{a_c}{A^{1/3}} + 4a_{as}$$

$$\Rightarrow Z = \frac{a_c A^{-1/3} + 4a_{as}}{2a_c A^{-1/3} + 8a_{as} A^{-1}}$$

$$\Rightarrow \boxed{Z = \frac{4a_{as} A + a_c A^{2/3}}{2a_c A^{2/3} + 8a_{as}}}$$

this is the Expression for most stable isobar.

(*) Using semi-empirical mass formula. Find the binding energy of (i) ${}_{20}Ca^{40}$, (ii) ${}_{19}K^{39}$

→ given $a_v = 15.5$ Mev, $a_s = 16.8$ Mev, $a_c = 0.7$ Mev, $a_{as} = 23$ Mev, $a_p = 34$ Mev.

$$BE = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} + (0, \pm a_p) A^{-3/4} - a_{as} \frac{(A-2Z)^2}{A}$$

(i) $Z = 20$, $N = 20$,

Pairing energy, $+a_p$.

$$\therefore BE = 15.5 \times 40 - 16.8 \times (40)^{2/3} - a_c \frac{20 \times 19}{(40)^{1/3}} + 34 (40)^{-3/4} - 23 \times 0.$$

$$= 620 - 16.8 \times 11.84 - 6.65 + \frac{34}{15.905}$$

$$= 620 + 2.137 - 205.562$$

$$= \underline{416.575 \text{ Mev}}.$$

(ii) $Z = 19$, $N = 20$

Pairing energy $= 0$.

$$\therefore BE = 15.5 \times 39 - 16.8 \times (39)^{2/3} - 0.7 \times \frac{19 \times 18}{(39)^{1/3}} + 0 - \frac{23}{39}$$

$$= 604.5 - 195.589 - 6.138 - 0.589.$$

$$= \underline{402.184 \text{ Mev}}.$$

(*) Find the most stable isobar for mass number $A = 56$

$a_v = 15.5$ MeV, $a_s = 16.8$ MeV, $a_c = 0.7$ MeV,

$a_{as} = 23$ MeV, $a_p = 34$ MeV.

→ Atomic number for most stable isobar

$$Z = \frac{a_c A^{2/3} + 4a_{as} A}{2a_c A^{2/3} + 8a_{as}}$$

$$= \frac{0.7 \times (56)^{2/3} + 4 \times 23 \times 56}{2 \times 0.7 \times (56)^{2/3} + 8 \times 23}$$

$$= \frac{\quad}{\quad}$$

$$= 25.24$$

$\simeq 26$ $\boxed{{}^{56}_{26}Fe}$ is most stable isobar, corresponding to mass no. 56.

Write down the evidance of nuclear shell model.

(*) In nuclear shell Model we consider that Proton's, nutron's form their individual shell's or orbit like structure similar to electron configuration.

For the closed shell of Proton and neutron the nucleus is more stable compare to nucleus with half filled or less than half filled shell.

There are many Physical Proves of nuclear shell model —

(i) Some nucleuses with Particular.

no. of Proton and nutron is more stable, this numbers are known as magic no.

Magic no.'s are – 2, 8, 20, 50, 86, 126. This magic no.'s cannot be explain using liquid drop model.

(ii) nucleus with magic no. proton's has high separation energy for proton as compared to other nucleuses in the naighbourhood.

(iii) nucleus with magic no. nutron's has high separation energy for nutrons as compared to other nucleuses in the naighbourhood.

(iv) Proton capture cross section or proton capture probability of a nucleus with magic no. proton's is very small as compared to naighbourhood nuclei. because the proton shell is closed for this nucleus.

(v) natron capture cross section or nutron capture probability of a nucleus with magic no. ~~protons~~ is very small as compared to neighbourhood nuclei. because the nutron shell is closed for this nucleus.

(vi) in liquid drop model it was consider that, the shape of the nucleus is sperical but in practical only the nucleuses with

magic no. Proton and nutron has spherical shape, other nucleuses has shape prolet and oblet.

(i) Write down the advantages of nuclear shell model over liquid drop model?

(ii) Write down the limitation's of nuclear shell model.

(iii) Explain the origin of magic no's. with mayer correction.

OR

Explain how magic no's represent closed proton nutron shell.

OR

with spin orbit interaction of proton nutron explain the magic no's,

(i) → Advantage's of nuclear shell model :-

(1) It explain's very well the existence of magic number's and the stability and high binding energy on the basis of closed shells.

(2) The shell model provides explanation for the ground state spins and magnetic moments of the nuclei.

(3) Nuclear isomerism, i.e existence of isobaric, isotopic nuclei in different energy state's of odd-A nuclei between 39-49, 69-81, 111-125 has been

explained with shell model.

i) → Limitation's of nuclear shell model are:-

(1) The model does not predict the correct value of spin quantum numbers in certain nuclei. Ex - $^{23}_{11}Na$ where the predicted value is $5/2$, the corrected value is $1/2$

(2) The following four stable nuclei $^{2}_{1}H$, $^{6}_{3}Li$, $^{10}_{5}B$, $^{14}_{7}N$ do not fit into this model.

(3) The model cannot explain the observed 1st exited state's in even-even nuclei at energies much lower than those expected from single particle excitation.

And also failed to explained the observed Quadrupole moment of odd-A nuclei, in particular of those having A-values far away from the magic number.

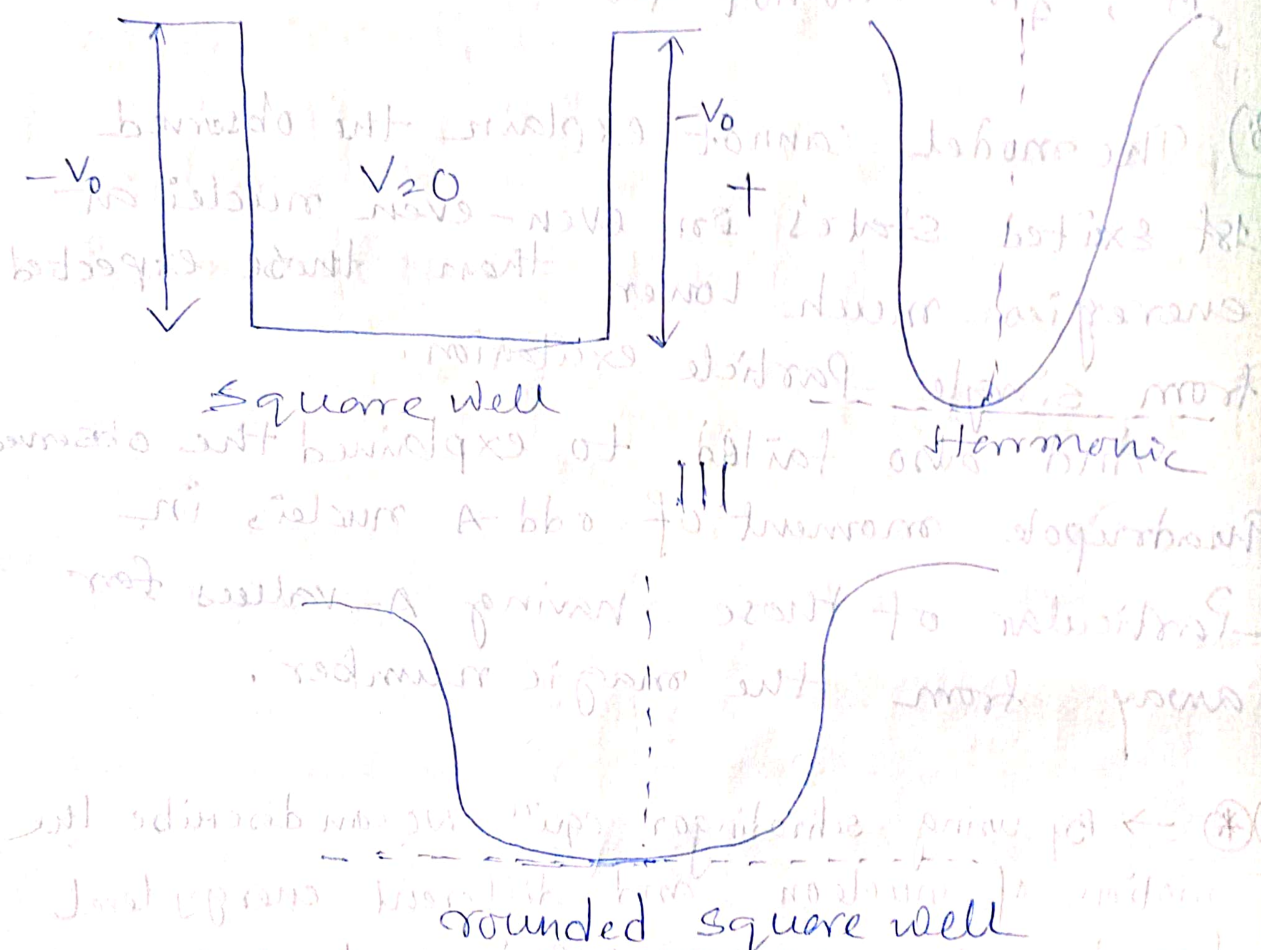
(5) (*) → By using schrodinger eqn we can describe the motion of nucleon and different energy level of nucleon in a nucleous. But we donot know the Exact Profile of nuclear Potential energy. (corrosponding to nuclear force)

So, we have to use Heat and trial method for nuclear Potential Energy. Scientist try with different Potential Energy like Square well Potential, otropic Harmonic Potential, wood-saxon Potential

$$\left[V(r) = \frac{V_0}{1+e^{(r-R)/a}} \right]$$

Yukava Potential $\left[V(r) = \frac{V_0 e^{-\mu r}}{r}\right]$, rounded square well Potential etc.

The best result was obtained by using rounded square well Potential. rounded Square well Potential is a hybridised Potential of square well Potential and harmonic Potential.



Using rounded square well Potential in Schrodinger's equ^n we get the energy level of nucleon's, $E_\lambda = (\lambda + \frac{3}{2})\hbar\omega$, where,

$\lambda = 0, 1, 2, 3, \ldots$

where, n = quantum no. for square well potential $\lambda = 2n + l - 2$,

l = quantum no. for isotropic harmonic Potential. $n = 1, 2, 3, \ldots$, $l = 0, 1, 2, 3 \ldots$

λ	Energy level $E_\lambda = (\lambda + \frac{3}{2})\hbar\omega$	(n, l)	nl (state)	$2(2l+1)$ no. of nucleon	Magic no.
0	$\frac{3}{2}\hbar\omega$	$(1, 0)$	1S	2	2 ✓
1	$\frac{5}{2}\hbar\omega$	$(1, 1)$	1p	6	8 ✓
2	$\frac{7}{2}\hbar\omega$	$(2, 0)$ $(1, 2)$	2S 1d	2 10	20
3	$\frac{9}{2}\hbar\omega$	$(2, 1)$ $(1, 3)$	2P 1f	6 14	40

by using rounded square well potential we can Explaine the only magic no 2, 8, 20 only. further magic no. can not be Explaine using rounded square well potential.

Mayer Correction:- Further Scientist mayer and his research group sugested that their is a spin-orbit interaction of Proton and nutron similler to electron.

the spin-orbit interaction energy.

$$V(r) = -\phi(r)\,[\vec{L}.\vec{S}] \quad \text{---(1)}$$

$\phi(r)$ = co-efficient depends on r

$\vec{L}$ = orbital angular momentum.

$\vec{S}$ = spin angular momentum.

total angular momentum

$$\vec{J} = \vec{L} + \vec{S}$$

$$\Rightarrow J^2 = (\vec{L} + \vec{S}).(\vec{L} + \vec{S})$$

$$\Rightarrow J^2 = L^2 + S^2 + 2\vec{L}.\vec{S}$$

$\Rightarrow J^2 - L^2 - S^2 = 2\vec{L}\cdot\vec{S}$

$\Rightarrow \vec{L}\cdot\vec{S} = \dfrac{J^2 - L^2 - S^2}{2} \longrightarrow$ (II)

Using equn (II) in equn (I).

$$V(r) = -\phi(r)\left[\frac{J^2 - L^2 - S^2}{2}\right],$$

$$= -\phi(r)\frac{[j(j+1) - l(l+1) - s(s+1)]\hbar^2}{2}$$

$J = \sqrt{j(j+1)}\hbar$

$L = \sqrt{l(l+1)}\hbar \longrightarrow$ (III)

$S = \sqrt{s(s+1)}\hbar$

We know that,

$j = |l+s| \cdots\cdots |l-s|$

$\therefore j = l + \frac{1}{2},\ l - \frac{1}{2}$ for Proton, nutron $S = \frac{1}{2}$

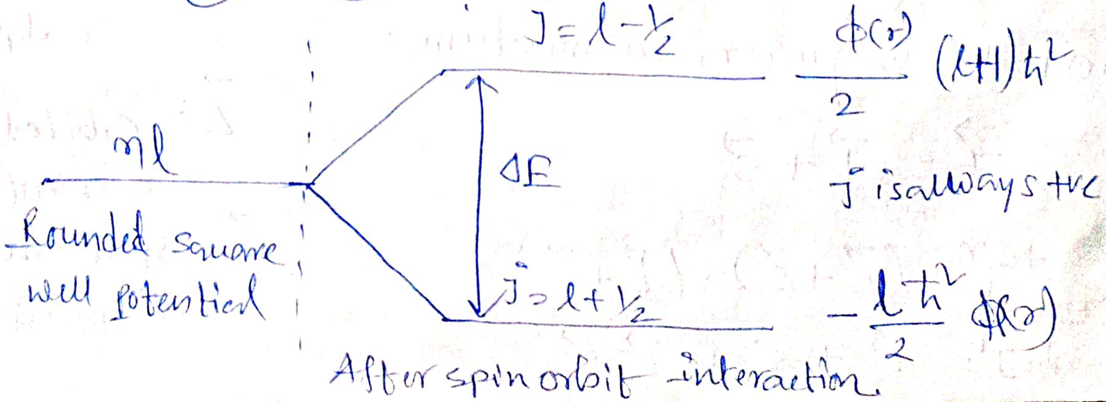
for, $j = l + \frac{1}{2}$, $s = \frac{1}{2}$

$$V(r) = -\frac{l\hbar^2}{2}\phi(r) \longrightarrow \text{(IV)}$$

for, $j = l - \frac{1}{2}$, $s = \frac{1}{2}$;

$$V(r) = \frac{\phi(r)}{2}(l+1)\hbar^2 \longrightarrow \text{(V)}$$

from equn (IV), (V)

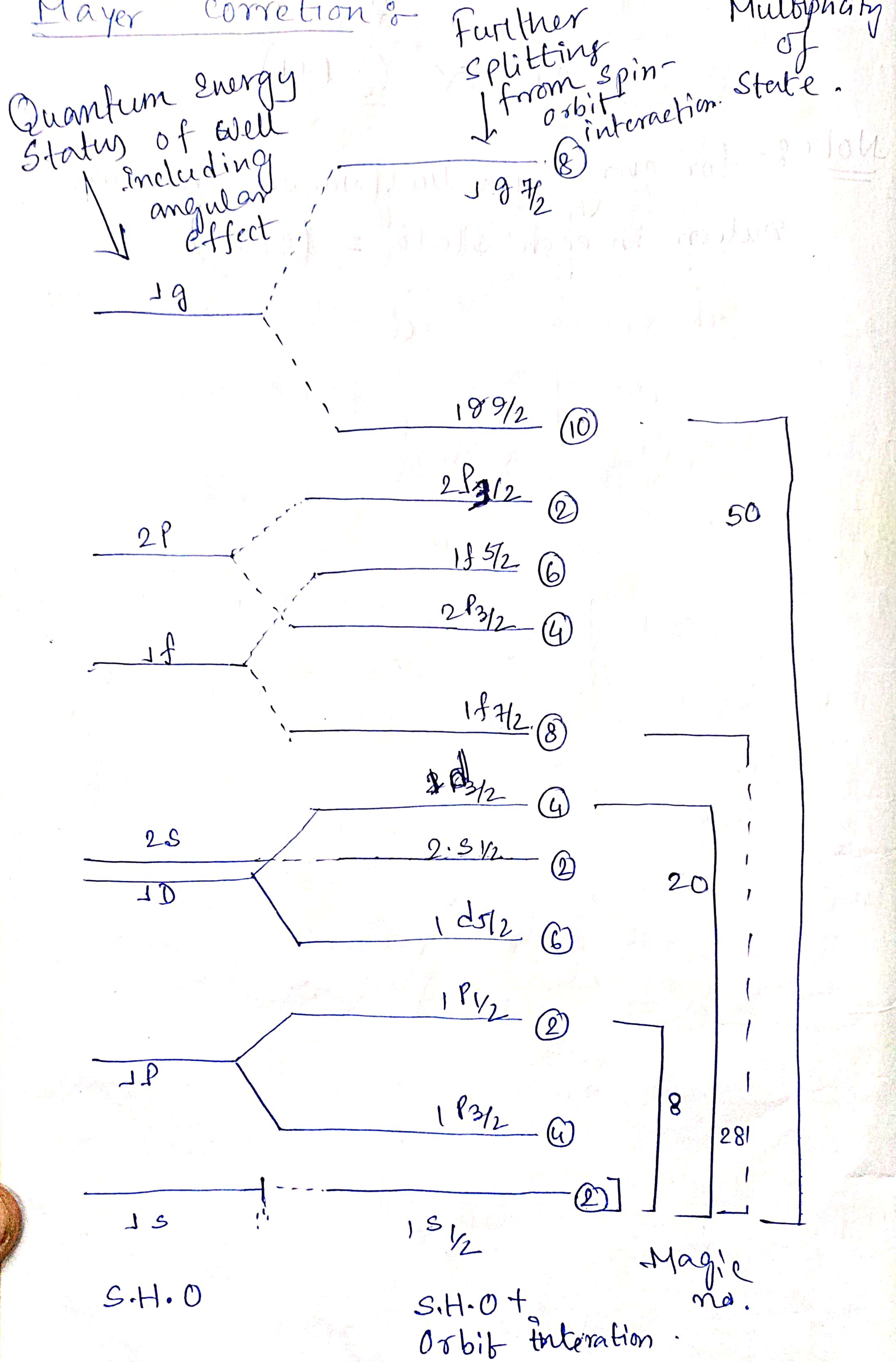


the energy gap $\Delta E = \frac{\phi(r)\hbar^2}{2}\left[2l+1\right]$

$$\Delta E \propto (2l+1)$$

Note:- for every j value, no. of Proton or neutron in each state $= (2j+1)$

Energy level digram of shell model after Mayer corretion :-



Application of shell model :-

By using shell model we can find the spin Pairity of a nucleus.

Case-I: nucleus with even even no. of proton - nutron, In this case there is no unpaire, proton ~~and~~ or nutron, that is why the spin of the nucleus is always zero. and Pairity is '+' because they are in Paired form.

$$\text{Spin Pairity} = j^{\pi} = 0^{+}$$

Case-II: nucleus with odd-no. of proton and even no. of nutron ~~or~~ odd no. nutron and even no. of Proton, in this case the spin of the nucleus = the 'j'-value of last unpaired proton/nutron. the Pairity of the state $= (-1)^{l}$; where l = orbital quantum number of last unpaired Proton/nutron.

Case-III: nucleus with odd-odd no. of Proton and nutron, In this case, there will be One unpaired proton and one unpaired nutron. for the unpaired Proton the last energy level $= l_P, j_P$

for the unpaired nutron the last energy level = l_n, J_n

the spin of the nucleus is given by Nordhern rule,

if $|l_p + j_p + l_n + j_n| =$ even

the spin of the nucleus $j = |j_p - j_n|$

if $|l_p + j_p + l_n + j_n| =$ odd.

the spin of the nucleus $j = |j_p + j_n|$

Pairity $= (-1)^{l_p + l_n}$

Find the spin pairity of following nucleuses:- (i) ${}_6C^{12}$, (ii) ${}_{19}K^{39}$, (iii) ${}_9F^{18}$ (iv) ${}_{19}K^{40}$

$\rightarrow$ (i) ${}_6C^{12}$, $P = 6$

$n = 6$

as there is even-even no. of Proton and nutron, spin-Parity $= 0^+$

(ii) ${}_{19}K^{39}$, $P = 19$

$n = 20$

$(1s_{1/2})^2 (1p_{3/2})^4 (1p_{1/2})^2 (1d_{5/2})^6 (2s_{1/2})^2 (1d_{3/2})^3$

for, unpaired proton, $j = 3/2$, $l = 2$

$\therefore$ Parity $= (-1)^l = (-1)^2 = +1$

Spin-Parity of this nucleus $= 3/2^+$

(iii) $_9F^{18}$, $p = 9$

$n = 9$.

for neutron, $(1s_{1/2})^2 (1p_{3/2})^4 (1p_{1/2})^2 (1d_{5/2})^1$

$j_n = 5/2$, $l_n = 2$.

for Proton, $(1s_{1/2})^2 (1p_{3/2})^4 (1p_{1/2})^2 (1d_{5/2})^1$

$j_p = 5/2$, $l_p = 2$

using Nordheim rule,

$$|l_p + j_p + l_n + j_n| = |5/2 + 2 + 5/2 + 2|$$
$$= 9 \text{ odd.}$$

∴ the spin of nucleus $= j = 5$

Parity $= (-1)^4 = +1$

∴ Spin-Parity of nucleus $= \cancel{5/2}\ 5^+$

(iv) $_{19}K^{40}$, $p = 19$

$n = 21$.

For Proton, $(1s_{1/2})^2 (1p_{3/2})^4 (1p_{1/2})^2 (1d_{5/2})^6 (2s_{1/2})^2 (1d_{3/2})^3$

$j_p = 3/2$, $l_p = 2$.

For neutron, $(1s_{1/2})^2 (1p_{3/2})^4 (1p_{1/2})^2 (1d_{5/2})^6 (2s_{1/2})^2 (2d_{3/2})^4 (1f_{7/2})^1$

$j_n = 7/2$, $l_n = 3$.

Using Nordhern rule,

$|l_p + j_p + l_n + j_n| = 10$ even

$\therefore j = |-2| = 2$

$\therefore$ Parity $= (-1)^5 = -1$

$\therefore$ spin-parity of nucleus $= 2^-$ Ans

(*) What do you mean by "Mean field theory" nucleus?

(OR)

Explaine "Mean field theory"

→ In atom the electron's are revolving arround the nucleus due to electrostatic interaction between the nucleus and electron's. But in case of proton and nutron's in nucleus, there is no such centre about which the proton and ~~elec~~ nutron can revolve. Scientist's assumed that the proton and nutron's experience's same nuclear force, which is the average of nuclear force of the whole nucleus (for 1 nucleon) and they revolve arround this mean force field of nuclear force. In this condition, we can describe the nature of whole nucleus by one nucleon only as ~~the~~ each of the nucleon experiences

Same force. This is known as "mean field theory" of nucleus.

Mean field theory is used in single particle shell model.

(*) Write down the assumption of fermi gas model of nucleus. Write down it's merits and limitations.

→ fermi gas Model

assumptions:-

(1) All Fermion's Occupy the lowest Energy States.

(2) Protons and nutron's are independent fermion filling two seperate potential well's.

(3) Common Fermi Energy for Proton's and nutron's is stable nuclei.

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(iii) ① → Packing fraction :- The ratio of the mass defect (mass difference between individual mass and ~~total~~ mass of nucleus) and the mass number of a nuclei is known as Packing fraction.

② → mass defect :- The difference in mass ~~and~~ of a nucleus and it's constituent nucleon is called the mass defect of that nucleus.

~~⑧~~ ⑤ → The ~~na~~names of various models of the nucleus is given by —

(i) Liquid drop model.
(ii) shell nuclear model.
(iii) compound nucleus model.
(iv) Fermi gas model of nucleus.

⑥ → Because, As the no. of Proton increases in a nucleus, the coulomb's repulsive force increasing, which tends to break the nucleus apart. so, to keep the nucleus stable, more no. of neutrons are needed, which are neutral in nature.

(7) → ~~For~~ The liquid drop model admits only a nuclear surface and interior. In contrast, shell models predicts energy shell and subshells, and therefore admit rich internal ~~substructure~~ substructure.

(8) → For the stability of nucleus some times nutron's are converted to proton and some times proton converted to nutron, when β-Partile emitt's from the nucleus.

... of synchrotron over cyclotron is

(9) → As the thickness of the material is increased, the fraction of the radiation passing through the material will decrease.

(10) → Particle accelerator is a divise used to accelerate different charge particle's to high velocity or high KE, which is necessary for many nuclear reaction's or experiment's.

No, we can't accelerate neutrons by cyclotron.

(11) → (i) Initial energy of α particle.

(ii) The range of α particle inversely proportional to the inonization energy of the gas.

(iii) The range of α particle is inversely proportional to density of the medium.

(iv) The range of α particle proportional to temperature and inversely proportional to ~~temp~~, pressure.

(13) → Isospin ~~of~~ as an abstract quantity, it is not physical quantity. In strong interaction between two particle's is independent of charge. To distinguish between nutron - proton we consider a quantum no. which is known as isospin.

(12) → Cherenkov radiation is a form of energy that we can perceive as a blue glow emitted when the electrically charged particles that composes atom's are moving at speeds faster than that of light in a specific medium.

(4) → The angular momentum of the nucleus is the combined contribution of the spin-orbit angular momenta of the constituent particles.